Evaluation of muscle oxidative metabolism in a bedridden population pre- and post-rehabilitation

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Abstract Long period of bed rest for elderly population, due to a femur fracture event, can cause a deterioration in the muscular capacity. Therefore, monitoring of the muscle oxidative capacity in this fragile population is necessary to define the muscular oxidative metabolism state before and after a rehabilitation period. TD-NIRS technique allows calculating the absolute values for the hemodynamic parameters, such as oxy- (O_2Hb), deoxy- (HHb), total- (tHb) haemoglobin, and tissue oxygen saturation (SO_2) of the muscular tissue. In this work, we will characterize muscle hemodynamics during a baseline period at two different time points: after the surgery (PRE) and after 15 days of rehabilitation (POST).

1 Introduction

Long period of bed rest for elderly population, due for example to a femur fracture event, can cause a deterioration in the muscular capacity. The physiotherapy intervention, starting from the day after the surgery, is crucial for avoiding or reducing the sarcopenic state of the patient muscle and allowing faster recovery. The evaluation of this intervention is done with a subjective evaluation of the patients and no objective marker for the muscle oxidative state and capacity in this

fragile population are, at the moment, used in the clinical environment [1]. This work is a first step in the assessment of the rehabilitation progresses with personalized and objective parameters related directly with the muscular tissue.

TD-NIRS technique allows to calculate the absolute values for the hemodynamics parameters, such as oxy- (O_2Hb), deoxy- (HHb), total- (tHb) hemoglobin, and tissue oxygen saturation (SO_2) of the muscular tissue in a non-invasive way directly at the patient bed [2,3]. These parameters will be evaluated during a baseline acquisition to estimate the oxidative muscular function at rest. The measurements were performed on the vastus lateralis muscle of the non-surgical leg of 15 patients and were considered at two different time points: before and after a 15-day rehabilitation period. The maximum voluntary contraction was also acquired to assess the improvements in terms of strength of the patients.

2 Methods

This study was approved by the Ethical Committee of ASST Gaetano Pini CTO and conducted in accordance with the Declaration of Helsinki on 15 female patients. They were seated on a chair, which allows to fix the knee angle at 120°. Firstly, they were asked to press the leg against the chair holder as strongly as the could, to determine the maximum voluntary contraction (MVC) during an isometric contraction of the quadriceps muscle. The power exerted was recorded by a load cell fixed to the chair holder. The MVC was then calculated as the average of three consecutive trials.

TD-NIRS measurements were performed with a device previously developed by the Department of Physics at Politecnico di Milano, widely described in Re et al. [4]. The optical probe was placed on the vastus lateralis of the non-surgical leg allowing measurements at two different interfiber distances: 1.5 and 3 cm. A 60 s baseline period was recorded at 1 Hz of acquisition rate. On the same site a ultrasonographic exam was performed to calculate the pennation angle (PA) and the adipose tissue thickness (ATT).

A two-step procedure was employed for the TD-NIRS data analysis. Applying the solution of the photon diffusion equation for a homogenous medium it is possible to calculate the nominal values for the optical properties, i.e. the absorption coefficient and the reduced scattering coefficient, at the two interfiber distances on the vastus lateralis muscle. A second fit, where these values are employed as initial values, based on a bi-layer medium, can be employed to determine the optical parameters for the two considered layers, one more superficial and the other deeper. In this way, it is possible to separate the contribution of the superficial and systemic compartments (skin, capillary bed and fat) from the muscular tissue. This method needs the knowledge of the ATT. Starting from the absorption coefficient for the deeper layer and employing the Beer law, we calculated the absolute values for the oxy- (O_2Hb), deoxy- (HHb) and total- (tHb) hemoglobin content, and the tissue

oxygen saturation (SO_2). The baseline values for all the previous parameters were calculated as the average of the last 10 s.

The MVC and the hemodynamic parameters were acquired at two different time points: the first one (PRE) at 6-8 days after the femur fracture and around 3 days after the surgery. The second one (POST) was identified at 15 days after the PRE; during this period, the subject followed a daily physiotherapy rehabilitation program.

The distributions for the population of all the parameters were represented with boxplots, and the mean, average and standard deviation were calculated. Relations between all different parameters at the two time points were investigated with Pearson coefficient correlations and one-way Anova analysis. Intra-subject variability was evaluated with the χ^2 test.

3 Results

The mean age among the 15 female subjects was 78.4±6.8 years; the ATT was 9.8±3.7 mm and the PA 9.2±5.0°. The MVC was: 254.8±44.4 N for the PRE and 312.9±80.6 N for the POST. In Figure 1, its distribution at the two time points is shown. We can observe that for the POST time point, the average values is higher but not significant different respect to the PRE but the population is more dispersed around the average. The intra-subject variability was not significant as well.

In Table 1, the absolute values for O_2Hb, HHb, tHb expressed in μM and SO_2 expressed in percentage, are reported for the PRE and POST period. For these parameters, the distribution of the population was more similar around the average for the two time-points. Also, for the hemodynamic parameters no significance differences were found both at group and single subject level.

Table.1 Oxy- (O_2Hb), deoxy- (HHb) and total- (tHb) hemoglobin and tissue oxygen saturation (SO_2) absolute values. PRE and POST: before and after 15 days of rehabilitation.

		AVERAGE	STANDARD DEVIATION
O_2Hb [µM]	PRE	49.1	14.1
	POST	47.1	13.4
HHb [µM]	PRE	28.3	10.3
	POST	26.7	9.9
tHb [µM]	PRE	77.3	23.6
	POST	73.8	21.4
SO2 [%]	PRE	63.9	4.0
	POST	64.2	5.6

4 Discussions and Conclusions

Nowadays, no techniques providing an objective assessment of the oxidative status of muscular tissue are routinely used in clinics. In this work, it was possible to characterize the vastus lateralis muscle of elderly and bedridden patients with TD-NIRS parameters. The absolute values for O_2Hb, HHb, tHb and SO_2 were calculated with a two step fitting procedure based on a bilayer model, which allows to enhance the contribution coming from the muscular tissue, with respect to the superficial tissue, where skin, capillary bed and fat are mostly present. The knowledge of the ATT thanks to the US acquisition allowed to estimate those parameters with a good accuracy.

We also compare the previous parameters in two different time-points: before and after a 15 days rehabilitation period and we observed that, there were no significance differences among the group values of all the considered parameters. Furthermore, also at the single subject level, no significance differences were found. These results suggest that for this kind of population, the baseline of the hemodynamic parameters is not the best parameters to consider to assess the rehabilitation progresses in terms of muscular oxidative metabolism. This could be due to the length of period considered, which could be not enough to stimulate changes in the basal muscular condition. To better understand these preliminary

data, it will be necessary to observe the population also during longer rehabilitation period. It will be also interesting to evaluate these patients always after 15 days of treatment, but during an exercise to observe if other outcomes related to oxidative metabolism, such as the SO_2 slope at the beginning of the inset of the exercise or at the beginning of the recovery period, are more suitable in the assessment of the rehabilitation progresses.

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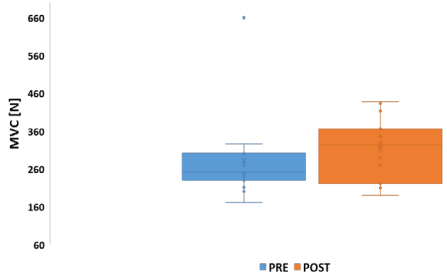

Figure.1 MVC: maximum voluntary contraction. Distribution at the PRE and POST time points.